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## ABSTRACT

This paper describes the measurement of the force exerted by the gas on a model disc valve as the gas escapes from the valve due to the disc being pulled from the stationary valve seat. The work forms part of a wider investigation of the aerodynamics of disc valves and reference is made to this.

## INTRODUCTION

In previously reported work (1) it was found expedient to simulate the valve opening phase by withdrawing the plenum cylinder from a fixed valve disc. It was felt that this method did not exactly reproduce the flow past a moving valve and that, if possible, measurements should be made with a moving valve and fixed seat. This is particularly important when considering measurement of gas forces on the valve while the valve is fluttering. The moving valve apparatus is shown diagrammatically in Fig. 1.

## EXPERIMENTAL EQUIPMENT

The main difficulty with the method of force measurement described here is the occurrence of the unwanted signal which results from the fact that the valve disc/transducer assembly is accelerating; i.e. the inertia force effects which, for much of the time, will be much greater in magnitude than the force exerted by the gas. Different methods of measuring the gas force were considered but all suffered from this disadvantage. Quartz piezo-electric transducers were chosen for several reasons, including:

a) a high natural frequency,

b) high stability,

c) linearity over the entire working range.

The unwanted inertia force signal was dealt with by "cancelling it out", so to speak, with an equal and opposite inertia force signal from a nominally identical force transducer/disc valve assembly mounted back to back with the main force transducer. This "compensation" transducer is indicated in Fig. 1.

Separate charge amplifiers were used for each force transducer, with a summing junction at the output (Fig. 2). [illegible] allowed adjustment of the gain of the compensating amplifier so that maximum cancellation of acceleration effects could be achieved.

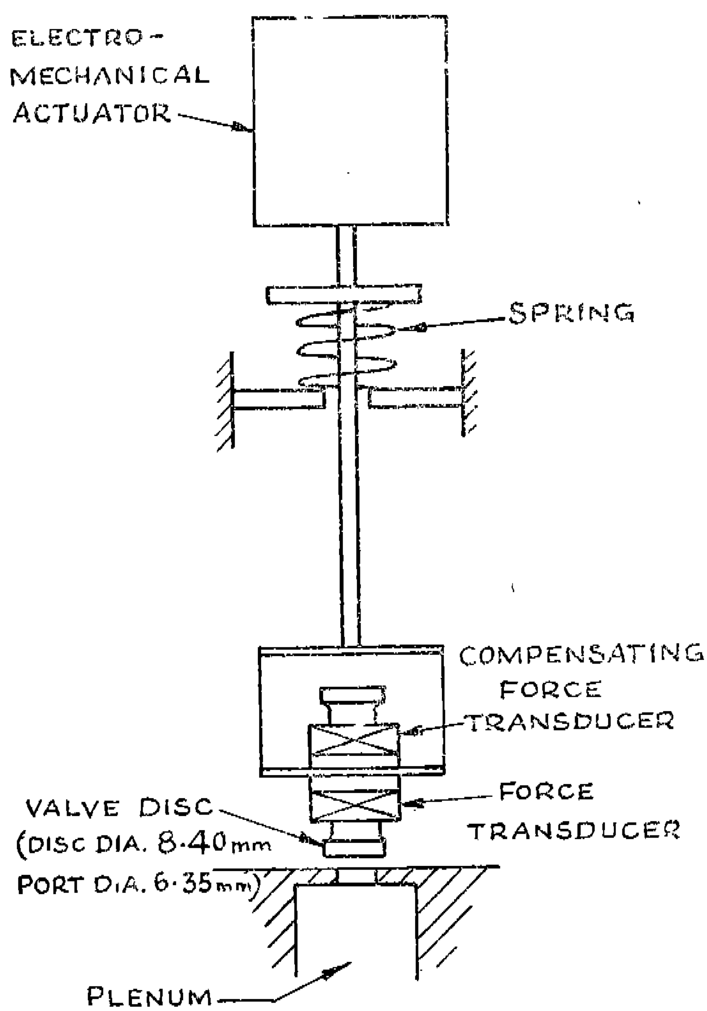



FIG. 1. DIAGRAM OF TEST RIG

It was not possible to achieve total cancellation, since unavoidable minor asymmetries of the rig led to small differential transverse motions of the transducers. The gas force signal to noise ratio so achieved was satisfactory for most purposes. However, any residual unwanted signal can be removed by digital subtraction. This is possible due to the highly repeatable nature of the experimental results from one test to the next.

The unwanted signal can, of course, be measured by operating the apparatus with zero gas flow. The recorded signal would be digitised and then subtracted from the previously digitised signal recorded during a test with air. The resulting signal should represent the effect of the air alone. Since the authors are still developing this technique, and its associated computer program, the results given in this paper were obtained by manual processing of the data.

Valve displacement was measured by means of a capacitive transducer, which was calibrated by making use of slip gauges.

Plenum pressure variations were measured by a piezoelectric pressure transducer. A calibrated pressure gauge was used to determine mean and datum levels.

The electro-mechanical actuator could be employed either to hold the valve down on its seat, or to vibrate the valve. A dc supply was provided both to provide the holding down force, and to set the mean position during oscillation. A superimposed ac supply gave oscillation at chosen frequencies.

The authors are also currently developing a hot wire anemometer system to enable the variation of gas velocity to be determined in magnitude and direction at stations in close proximity to the valve disc, as the disc moves relative to the seat either in flutter or in a transient pull-off test. The system is described elsewhere (2).

TEST RESULTS

The force measurements at fixed increments of valve lift (see Fig. 4) were made by setting the plenum pressure to the desired value (in this case 6 or 12 psi) and then recording the force signal which is obtained when the air is suddenly switched off. The force measuring system was calibrated using a Kistler charge calibrator (type 5351). The force transducers and the charge amplifiers were also made by Kistler. These steady-state values of force were compared with the gas force on the valve during a transient pull-off motion. Hard copies of typical oscilloscope traces of displacement and force for pull-off tests are shown in Fig. 3. The graphs of force against displacement derived from these traces are shown in Fig. 4.

Two features of the graphs shown in Fig. 4 seem worthy of comment. The first is that the force during the transient pull-off test in the very early stage of opening, is significantly smaller than the corresponding force caused by steady-state flow with the valve lift fixed at that small opening. This

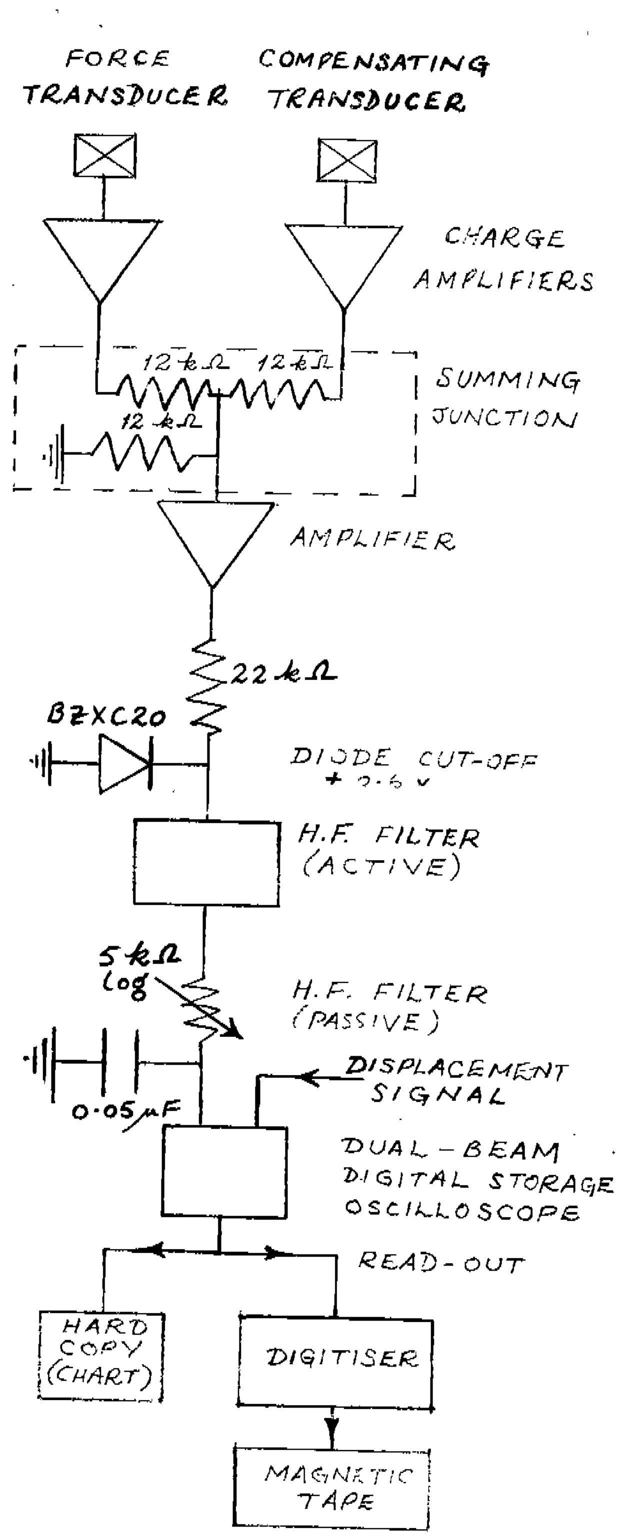



FIG 2

FORCE MEASURING SYSTEM

FIG. 3. TYPICAL OSCILLOSCOPE TRACES.

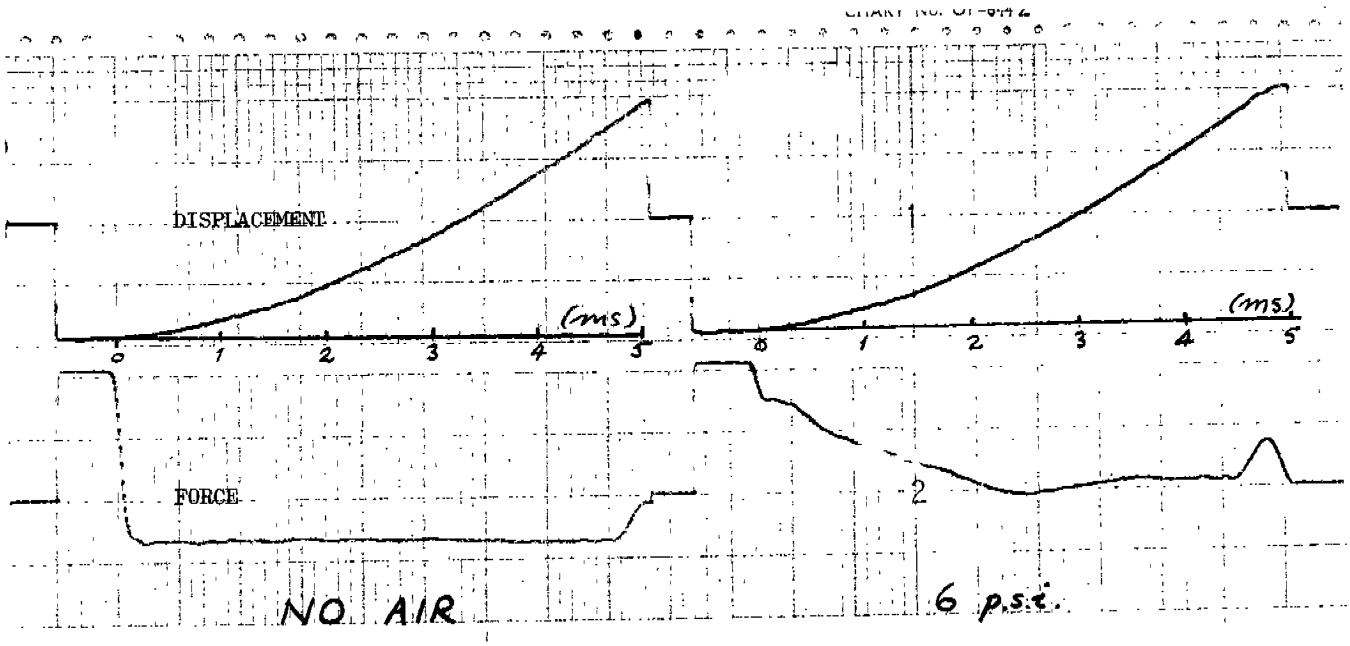
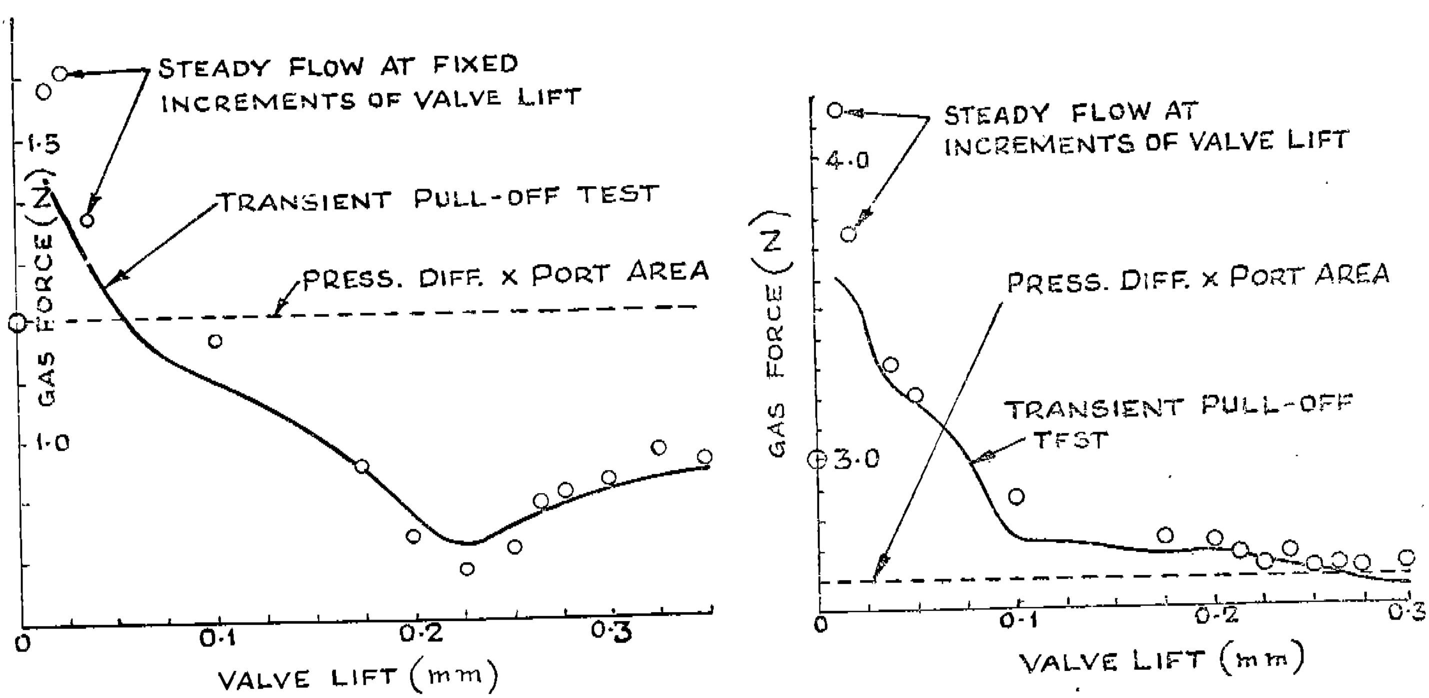



FIG. 4. GAS FORCE v VALVE LIFT




6 p.s.i 12 p.s.i.

was a feature reported by Brown et al (1) in 1976 and is confirmed here. The most likely explanation for this is that in steady flow the gas has established a significant pressure over the annular overlap region, whereas in the transient pull-off test starting from the closed position, in 0.5 ms or so, the gas has not had enough time to establish such a large pressure in this region.

The second feature is that the gas force in both the steady-state and transient tests passes through a minimum value for a pressure difference of 6 psi but not for 12 psi. This apparently pressure dependent phenomenon remains unexplained. It is hoped that the hot wire anemometer program will shed some light on the problem. It appears that at a valve lift of around 0.23 mm, an abrupt change in flow pattern occurs for a pressure of 6 psi.

When the pressure difference is 6 psi and the valve is closed, there is very close agreement between the measured value of gas force and that calculated by multiplying the port area by the pressure difference. In the case of 12 psi the measured force is higher than the value calculated in this way. This is almost certainly due to the sealing of the valve partially breaking down at 12 psi. This would expose part of the annular sealing area to gas pressure. The result would be a gas force on the valve in excess of the value given by pressure times port area.

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